

Properties and Classifications of Matter

PS-3 The student will demonstrate an understanding of various properties and classifications of matter.

PS-3.1 Distinguish chemical properties of matter (including reactivity) from physical properties of matter (including boiling point, freezing/melting point, density [with density calculations], solubility, viscosity, and conductivity).

Taxonomy Level: 4.1-B Analyze Conceptual Knowledge

Key Concepts:

Physical property: boiling point, freezing/melting point, density, solubility, viscosity, conductivity

Chemical property: combustibility, flammability; ability to oxidize, corrode, decompose, react with acids; not react

Previous/Future knowledge: Students were introduced to this topic in 7th grade (7-5.9).

A more in-depth understanding of the actual processes is expected for Physical Science.

Distinguishing between physical and chemical properties is the foundation for an understanding of the distinction between chemical reactions and physical change (PS-4.6) and, therefore, vital to an understanding of chemical reactions in (PS-4.7) through (PS-4.11) and all future chemistry courses.

It is essential for students to know the criteria for distinguishing chemical from physical properties:

- A physical property of a substance is a characteristic of the substance that can be observed directly or measured with a tool without changing the composition of the substance.
- A chemical property is a description of the ability of a substance to undergo, or not undergo, a change that will alter the composition of the original substance.

Physical Properties

It is essential for students to understand the following physical properties:

Boiling point, freezing/melting point – students should

- Know that the terms boiling point and melting/freezing point do not refer to the phase change itself, but to a measurement: the temperature at which these changes occur.
- Understand that the composition of a substance does not change during phase change nor does it change when one measures temperature in order to determine the boiling point, and freezing point/ melting point, therefore, boiling point and melting/freezing point are physical properties.

Misconception:

As the physical appearance of a substance changes during a phase change, students often mistakenly assume that evaporation and freezing/melting are chemical changes (see PS-4.6).

This misconception is often encountered with evaporation where students confuse vaporization of material A from liquid (A) to gas (A) with the formation of a new gas (B) by a chemical reaction.

It is not essential for students to

Understand the effect of pressure on the boiling point or the freezing/melting point of a substance.

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Density – students should

- Understand the concept of density as the mass of a substance per unit volume. A conceptual understanding of density ensures that students understand why the density of a particular substance (under constant conditions) is always the same, regardless of the sample size.
- Understand why the density of a substance changes with phase change. PS-3.7 addresses the difference in the particle arrangement in solids, liquids and gases. Students should understand that because the volume of a particular substance is dependent upon phase, the density of a particular substance is as well.
- Understand that density can not be measured directly, but is the ratio of two measurements: mass and volume.
 - Students must have a strong conceptual understanding of mass and volume.
 - In addition, it is essential that students understand and are proficient at carrying out the procedures for accurately measuring the mass and volume of solids (regularly and irregularly shaped) and liquids (PS-1.3).
- Understand and calculate density using the formula: $\text{density} = \text{mass}/\text{volume}$.
- Understand that the composition of a substance does not change when one measures mass and volume in order to calculate density; therefore, density is a physical property.

Misconception:

Students can often manipulate and solve the density equation without a grasp of the proportional thinking required to truly understand the concept. Understanding a ratio requires that students think abstractly, a cognitive skill that many physical science students have not yet acquired. Therefore, it is essential that this concept be introduced in a concrete manner.

It is not essential for students to

Understand the effect that temperature change (apart from phase change) has on volume (therefore, the density) of solids, liquids, or gases.

Solubility – students should

- Understand that a substance is soluble in a solvent if it will dissolve in that solvent. The term solubility is defined as the maximum amount of a solute (substance being dissolved) that can dissolve in a given volume of solvent (the dissolving medium) at a particular temperature and pressure.
- Understand that a *saturated* solution is one in which the maximum mass of the solute is dissolved in the solvent at a particular temperature.
- Be able to give examples of solids, liquids, and gases that readily dissolve in water and to realize that some materials are not soluble in water.
- Understand that the components of solutions and other mixtures do not chemically combine to form a new substance. Solutions are composed of two substances which each retain their own properties. Therefore, solubility is a physical property.

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Note to teachers:

In Physical Science, solubility is defined as a physical property because solutions are defined as homogeneous mixtures. As students study chemistry they will find that the dissolving process varies with the characteristics of the solute and the solvent respectively. The attraction of various solute particles to water molecules varies and if this force is strong, the dissolving process is followed by reactions that are chemical in nature as the solute particles interact with the solvent particles. It is not essential for Physical Science students to be aware of this, but if they find conflicting information in texts, an explanation should follow.

Misconceptions:

- Students often confuse solubility with the rate of dissolving (see PS-3.5).
- As the physical appearance of a substance changes when it dissolves (the solute often disappears) students often mistakenly assume that dissolving is a chemical change (PS-3.6). In a solution, the solute and solvent do not chemically combine, they form a homogenous mixture. (PS-3.4)

It is not essential for students to

- Consider solubility of substances in solvents other than water.
- Consider the effect of pressure on solubility.
- Predict the effect that temperature has on the solubility of a given substance. (It is interesting, but not essential, to contrast the effect that temperature has on the solubility of gases versus most solids and to consider the many results and applications of temperature-dependent solubility in our world.)
- Understand how to read temperature vs. solubility graphs.

Viscosity – students should

- Understand that viscosity is a property of fluids (focus on liquids, not gases).
- Understand that viscosity is a measure of the material's resistance to flow. High-viscosity fluids take longer to pour than low-viscosity fluids.
- Understand that viscosity may change with temperature.
- Understand that the composition of a fluid does not change when it is poured and, therefore, viscosity is a physical property.

It is not essential for students to

Use specialized apparatus to test and measure viscosity.

Electrical Conductivity – students should

- Understand that the ability of a solid to act as an electrical conductor or an electrical insulator is based on the solid's ability to complete an electric circuit, i.e., conduct electricity. (see indicator PS-6.9 for electric circuits)
- Understand that materials (such as metals) with high conductivity are called electrical conductors because they allow current to flow easily.
- Understand that materials with low conductivity are called electrical insulators because they do not allow current to flow. Most non-metals are insulators.

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- Understand that some solutions can conduct electric current, depending on the nature of the solute. Solutes that dissolve in water that result in solutions that allow electric current to flow are called *electrolytes*. Electrolyte solutions contain *ions*.

It is not essential for students to

Know the relationship among the terms electrical conductor, electrical resistivity, and electrical resistance.

Chemical Properties

It is essential for students to

- Understand that a *chemical property* is a characteristic of a substance that indicates whether it can or cannot undergo a certain chemical change.
- Understand that the process of chemical change produces new substances with new identifying properties.

Chemical properties include but are not limited to:

- *Combustibility or flammability*, such as carbon reacting with oxygen to form carbon dioxide. (example, burning charcoal), or hydrocarbons reacting with oxygen to form carbon dioxide and water vapor (example, burning of fossil fuels)
- *Ability to oxidize*, such as iron reacting with oxygen to form iron(III) oxide. (iron rusting)
- *Ability to corrode*, such as silver reacting with sulfur to form silver sulfide. (silver tarnishing)
- *Ability to decompose*, such as hydrogen peroxide decomposing into water and hydrogen gas when exposed to light.
- *Ability to react with acids*, such as zinc reacting with hydrochloric acid to form zinc chloride and hydrogen gas.
- *Ability to not react*, such as gold being used in jewelry because it does not readily react.

Assessment Guidelines:

The objective of this indicator is to *distinguish* chemical properties of substances from physical properties (solubility, viscosity, conductivity, density, boiling and freezing point), therefore, the primary focus of assessment should be to identify the relevant or important aspects of each property necessary for classification. In this case, the composition of the substance does or does not change when the property is measured, as well as an understanding of the distinction between chemical and physical properties.

In addition to distinguishing chemical and physical properties, assessments may require that students:

- *Classify* properties as physical or chemical.
- *Identify* physical and/or chemical properties of a substance.
- *Exemplify* (give examples) chemical and physical properties.
- *Use* the mathematical formula for density to solve for one of the variables when given the other two.